Humans, Harmony and the Anthropocene: A new Epoch of the Earth System

Mark G. Lawrence
Institute for Advanced Sustainability Studies

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In the spring of 1991 – a year before the first Earth Summit in Rio – I visited a friend of mine who was doing an internship at NASA Langley Research Center. He was assigned to a project which was looking at the concept of "terraforming". This was the idea that we could go to Mars and build large factories that would intentionally produce greenhouse gases, which would create a super-greenhouse effect, warming the planet enough that water and carbon dioxide would begin to escape from the planet's crust. From there we could take step-by-step measures to produce oxygen, and introduce vegetation and animals…eventually greening the red planet, and making it habitable for humans – and all this within 200 years.

Needless to say, this was a fascinating time in the evolution of our environmental consciousness. Concern over environmental pollution and depletion of resources had built up to the point of realizing that the Earth might one day become uninhabitable – or at least highly inhospitable – to humans. On the other hand, some were thinking that we'd soon have everything under control on Earth,but then we'd get bored, or overcrowded, and eventually need another home or playground somewhere. So, the thought was, we better be prepared with a backup solution for these possible "crises" (if you will)…and why not Mars? And amazingly, this idea caught on so well that it made the front page of an issue of Life Magazine (Figure 1), which shows a picture of Mars, and the headline "Our Next Home".

Note the conspicuous lack of a question mark in that headline! (I've added a couple here). Quickly enough, the hype died down once some serious calculations were made of the energetic and material limitations of this kind of "terraforming". And of course, the self-reflective question arose: was this not some kind of misguided hubris? Did we really think that we could custom-make a designer atmosphere, hydrosphere, lithosphere, and biosphere of another planet, when we can't even manage to understand and respect the Earth well enough to begin living in harmony with nature here?

Since the time of this magazine issue, like many others in my field I've spent considerable effort thinking in the difficult gray-zone between the suggested promise and the reflected hubris of planetary engineering, though applied to Earth, rather than Mars – but I'll return to that later. First I'd like to come back "down to Earth" and tell you some about Earth System Science, its immense complexity, and the connection of this to the Anthropocene and Harmony with Nature.

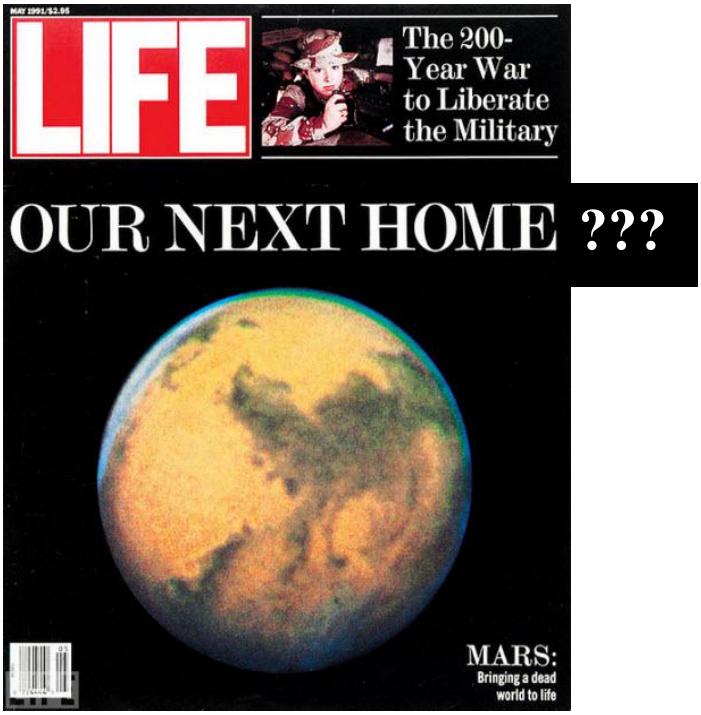

Figure 1: Cover of Life Magazine from May, 1991 [rights obtained from Getty Images]

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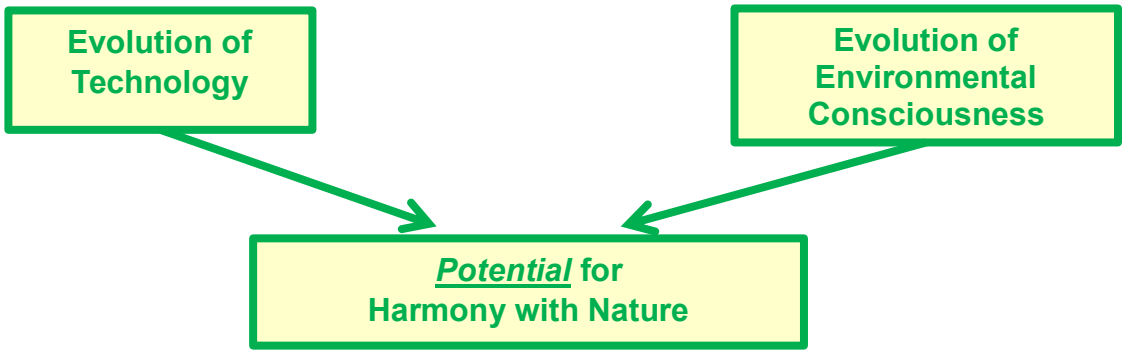

Figure 2: The possibility of combining the ongoing development of technology with the evolution of our environmental consciousness to develop a society living in greater harmony with nature.

The topic here is, broadly, Harmony with Nature. Now, take a look at the first box on the top left of Figure 2; doesn't it make you think: "Harmony with Nature and Evolution of Technology – what on Earth could be farther apart than those two?"

Well, taken by themselves, that certainly seems to be the case – but imagine we add to this the "Evolution of our Environmental Consciousness", which is a phrase I've begun using lately to reflect an aspect of our social development, consisting of two main components: our overall understanding of how nature works, and our collective relationship with and attitude towards nature.

Taken together with the evolution of technology, doesn't the ongoing evolution of environmental consciousness provide us with an unprecedented opportunity to develop beyond our generally dominating or adversarial relationship with nature towards a more sustainable, harmonious relationship?

But if this potential exists, then why doesn't it simply work? What's getting in the way?

Well, it's easy to think of many factors: For instance, we are often stuck in the old "habits" and cultural patterns that we are used to, and it is a basic effort to change these patterns, even when we know that this would benefit us. On a personal level, this is familiar to many of us, for instance in terms of eating well and exercising. In a larger social sense, most prominent amongst these is the pattern of exploitative, short-sighted, unsustainable consumption and production.

This difficulty in changing behaviors is often linked with what psychologists call cognitive dissonance, which is essentially irrationally talking ourselves into believing that something is safe or generally "okay" to do, even if our rational knowledge clearly tells us that it isn't.

These problems are compounded by the vast and rapidly growing population of the world.

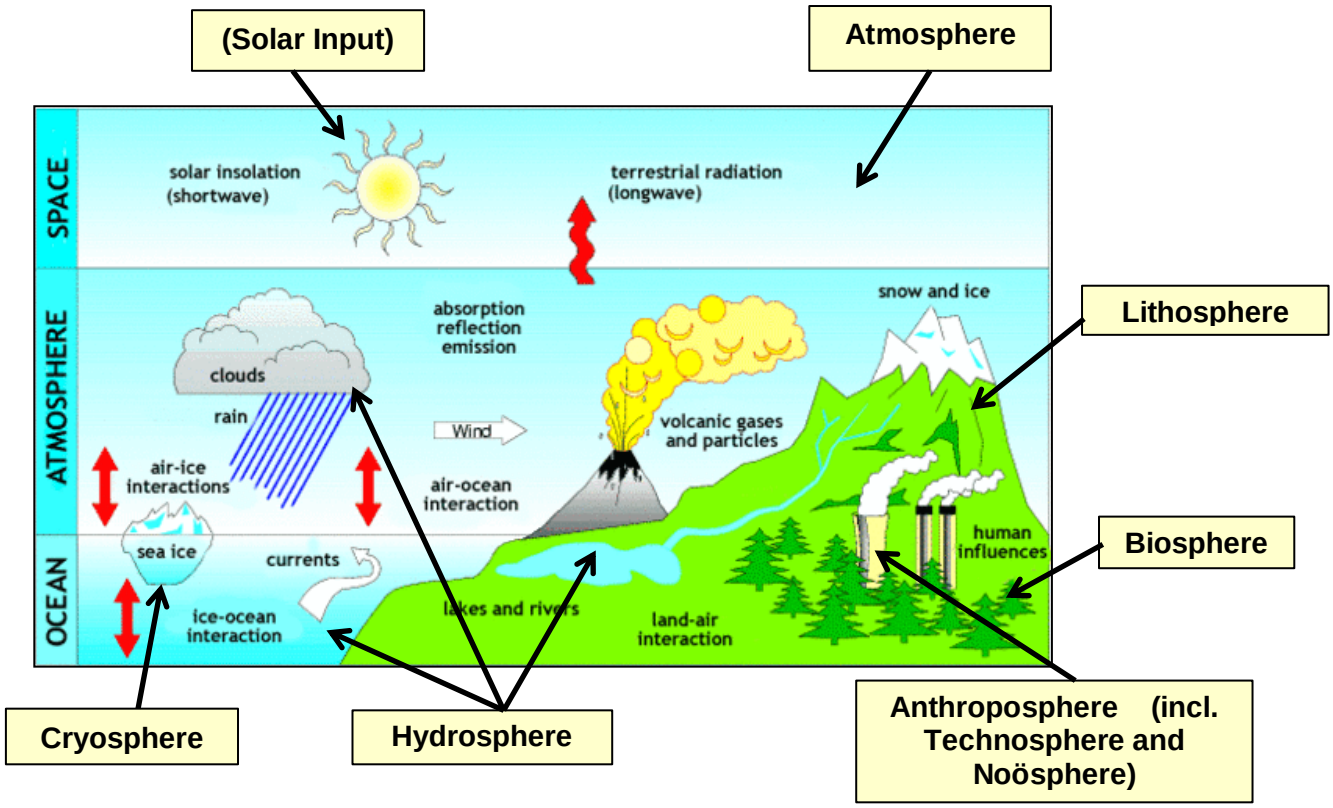

Figure 3: The Earth System (source: Max Planck Institute for Meteorology, http://www.mpimet.mpg.de/typo3temp/pics/533ba9422c.gif).

And finally, knowing how to approach the transition to sustainable living is made even more difficult due to the immense complexity of the Earth System – even before we add humans into the equation. The complex Earth System: to give you a quick overview of what this includes, Figure 3 provides a schematic showing its main components: the atmosphere, the lithosphere (the solid earth), the hydrosphere (liquid water in the oceans and rivers, as well as atmospheric water vapor and liquid and ice in clouds), the cryosphere (the frozen earth), the biosphere and the anthroposphere. The anthroposphere includes both the technosphere, all of our industrial developments, and the noösphere, which is our collective consciousness. Each of these is connected with each other in space and time through the innumerable processes in the earth System, resulting in an immense complexity through these connections. Thus, looking at any one component in isolation gives only a very limited picture of its behavior in the context of the Earth System as a whole.

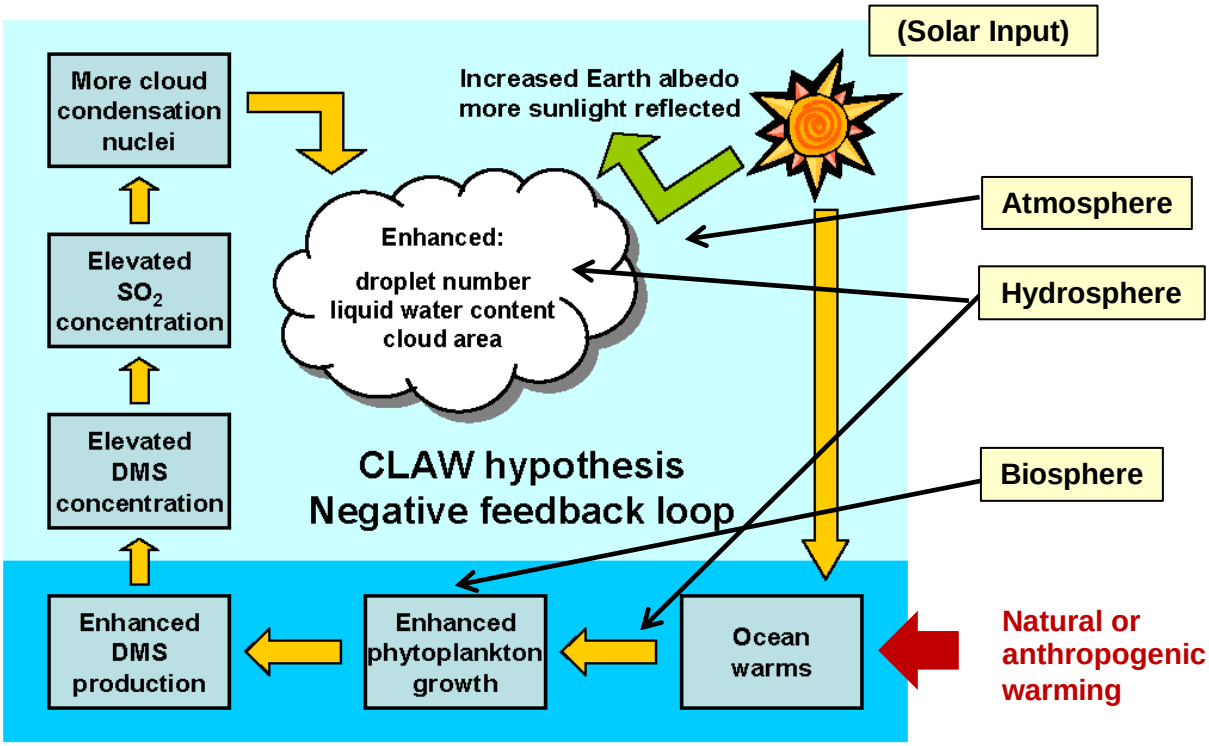

Figure 4: The hypothesized connection between plankton, dimethylsulfide (DMS), clouds and the climate (based on Charlson, Andreae, Lovelock and Warren, *Science*, 1987; source: http://en.wikipedia.org/wiki/File:CLAW_hypothesis_graphic_1_AYool.png).

This complexity and degree of interconnectedness of course makes it difficult to know how to "clean up our messes" that we have made in the environment. It has also been reflected in the development of global earth system models over the past decades. If we look back at the 1970s, climate models were fairly simple and only represented the atmosphere and the input from solar radiation. In the 1980s, surface processes like a simple hydrology were introduced. In the 1990s, the atmospheric models were coupled to models of the ocean and sea ice, and over the last decade a major development has been the inclusion of dynamic vegetation models, and improving the way that we represent the human influences on the environment. Thus, for the next IPCC, most institutes that are participating will be using very complex earth system models rather than simple climate models, though of course there is still far to go in terms of the detail of how each of these components and the many processes that occur in the earth system are

represented in these models.I would like to give you an example (Figure 4) of one of the very many connections between the different components of the system, demonstrating a complex *natural* cycle which connects the biosphere, the hydrosphere and the atmosphere, which does not necessarily involve the influence of humans. This is based on a paper that was published 25 years ago. A lot of work has been done on this since then, showing that there is a great deal more complexity to the cycle, but for this discussion, I am just going to show you the very simple version as was originally proposed. Let's start at the bottom right of the figure and go through the cycle clockwise. Imagine that the oceans warm for some reason (this could either be for natural reasons, such as glacial to interglacial transitions, or caused by humans). Laboratory studies show that phytoplankton grow more effectively in warmer waters (they also grow better when they receive more sunlight, which makes sense). Phytoplankton do many things in the oceans. One of those is that they produce a gas called dimethylsulfide (abbreviated "DMS"). DMS builds up in the surface waters of the oceans and escapes to the atmosphere, where it then gets converted into other forms of sulfur-containing gases, like sulfuric acid. Sulfuric acid molecules are very fond of sticking to each other, so they condense into tiny particles. These particles are very important for the formation of clouds, and normally when we have more of these little particles, the same amount of water in clouds will be spread across a greater concentration of smaller droplets, which makes them brighter. So if we start off with the warming the oceans, we will have more DMS being produced, more getting into the atmosphere, more of the tiny particles that are formed when DMS is broken down, and thus brighter clouds which reflect of more sunlight, which in turn reduces the amount of sunlight reaching the ocean surface, acting against the initial warming. In the end we started off with a warming, and due to this coupling through the biosphere, hydrosphere and atmosphere we end up with a reduction of the original warming. What is not yet clear is how strong this negative feedback is (that is, by how much the original warming is decreased), or even if it really works this way, since many other factors could interfere (for instance, changes in wind speed, or in the mix of phytoplankton species in warmer waters). This kind of dampening of an initial perturbation is what we call a "negative feedback". There are very many of these negative feedbacks in the Earth system, some stronger, some weaker. There are also many positive feedbacks, which go in the opposition direction, making an initial perturbation even stronger. For instance, when Arctic waters are warmed, the resulting decrease in the amount of sea ice makes the waters darker, so that they absorb more sunlight, heat up more quickly, and lead to even greater warming and further reduction of sea ice. Now, as I indicated above, this is an example of the extreme complexity of nature. What about the role of humans? How do we influence the Earth system? Humans have very many different effects on the environment. I like to split these into two types of effects: unintentional and intentional. The term unintentional in this sense means side effects on the environment – which we may be well aware of – which occur due to the activities that are done for other purposes, for instance for producing energy, or for transportation; emissions from power plants and cars are good examples. These activities lead to various types of undesired environmental

changes. Much attention is given to two of the main effects, namely air pollution and climate change. As a quick aside, it's worth noting that although these two are often treated separately, there are important links between them, and international attention is now being given to this through programs such as the Climate and Clean Air Coalition (CCAC http://www.unep.org/ccac/), which are focusing on reducing "SLCPs" – short lived climate-warming pollutants: about 1/4 to 1/3 of the warming that we have experienced so far since pre-industrial times is due to air pollutants like soot and ozone. There are also many other unintentional effects of our activities on the environment: among these are water pollution, soil degradation, noise pollution and electromagnetic pollution. On the other hand we have a number of intentional impacts through targeted environmental modification. These modifications range from the very smallest scales of building houses and other buildings, to the large scales of modern agriculture, deforestation, damming rivers, dredging canals, straightening rivers and so on. And it continues on to even larger endeavors, which I will return to later.

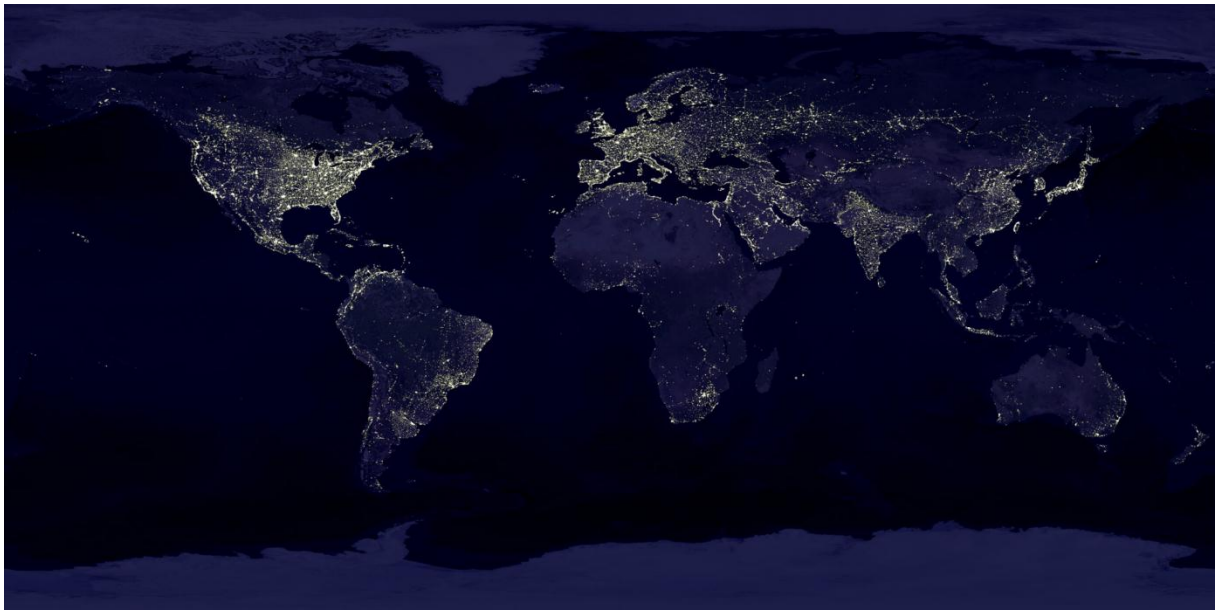

Figure 5: The Earth at Night (from http://eoimages.gsfc.nasa.gov/ve//1438/land_lights_16384.tif).

Our effects on the global environment show up in many ways. One of the most poignant of them is the image of the Earth at night, shown in Figure 5, which most of you have probably already seen. But while this gives an impression of the planetary nature of our impacts, it is almost a picturesque view. The dark side is seen in the many long lists of our

impacts in assessments like those of the IPCC: innumerable extinctions, extensive modification of natural cycles of elements like carbon and nitrogen, depletion of many natural resources, rising sea levels, melting glaciers and polar ice, desertification, and initial evidence of changes in the frequency and intensity of extreme events like droughts, floods, hurricanes, and so on. This human legacy has led us to introduce a new term into the field: the “Anthropocene”. The term Anthropocene is being developed in recognition of the fact that humans have become a planetary scale force in shaping the face of the earth and its atmosphere on geological time scales. Technically, the Anthropocene is a new epoch following the Holocene. The Holocence is approximately the last 10,000 years – the stable warm climate period since the end of the Pleistocene (the last ice age). The term Anthropocene was coined about three decades ago by the late Eugene F. Stoermer, and was made popular in the last decade by many proponents of the term, in particular the Nobel laureate Paul Crutzen. It is now widely (though not yet universally) accepted among scientists. One of the major open debates is when the Anthropocene started – when was the transition between the Holocene and the Anthropocene? Some say we should go back several thousand years, to the time when we started clear-cutting forests for agriculture. Others say it began more recently, with the industrial revolution, which is the most popular starting point in current discussions. Some place it even more recently, with the great socio-technical transition that has been occurring since the 1950s. Ban Ki-Moon talks about the great acceleration that we have been undergoing in the last 50 to 60 years. Some researchers are calling that “stage two” of the Anthropocene, during which we have undergone a radical reorganization of society, an explosion of technological evolution and substantial development of unsustainable consumption and production patterns which have led to the tremendous changes in the environment noted before.Geological time scales are very long. Figure 6 gives an overview of the geological history of the Earth. In the middle of the figure you see the large, familiar periods of the Triassic and the Jurassic, when the dinosaurs lived. The tiny little Epoch at the top left of the figure is the Holocene, and added on to the end of it would be the Anthropocene (it was not included when this depiction was made). Not only are we having impacts on the Earth on planetary spatial scales, as shown in Figure 5, but also long-term changes on geological timescales. For instance, many changes that we have caused in atmospheric composition (e.g., the elevated concentrations of CO_2 and N_2O) will last for hundreds of years, and be evident in sediment and ice cores over long periods afterwards. Even more devastating as a legacy is likely to be the mass extinction which we are causing, which may eventually be evident in the fossil record to a degree comparable to the extinction of the dinosaurs. This planetary, long-term impact is the reason that we call this new Epoch the Anthropocene.Now, if we look into the future at what kinds of challenges we will be facing in the Anthropocene, there are of course very many. One of those that I think is critical to point out in this forum, especially with respect to concept of the Anthropocene, is the possibility that some individuals, organizations, nations or coalitions may eventually pursue targeted environmental modification at the very largest scales, namely what we call “climate engineering” (also commonly, though less precisely, known as “geoengineering”).

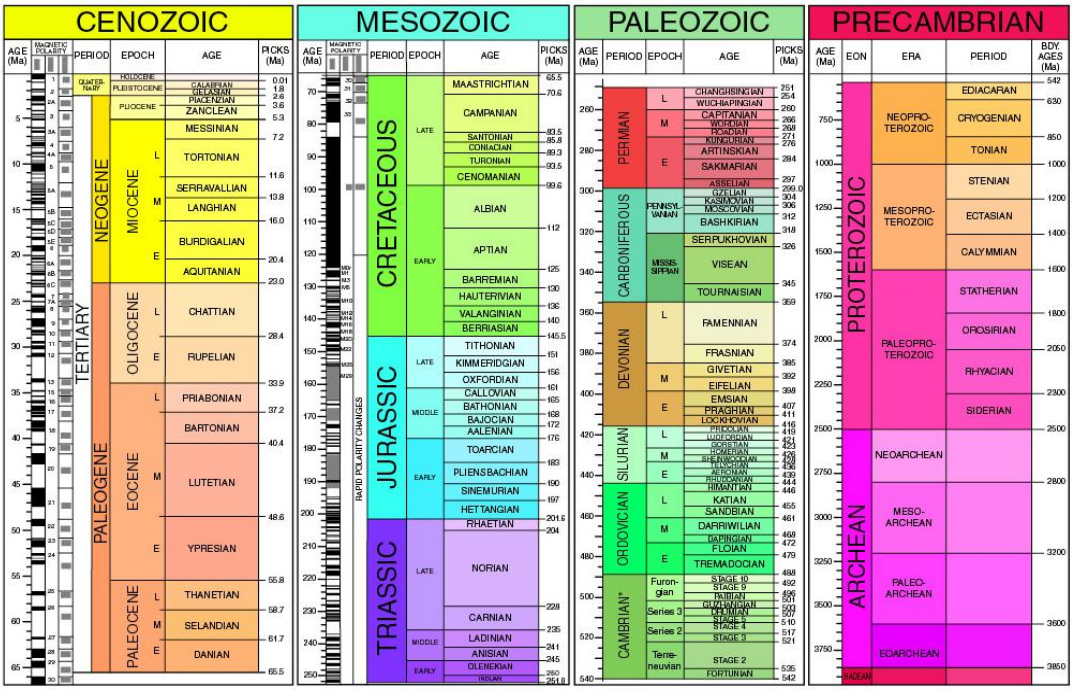

Figure 6: The geological history of the Earth (http://www.geosociety.org/science/timescale/).

There are a number of possible climate engineering measures which have been discussed, some of which are depicted in Figure 7. These measures can be largely divided into two types. One is the removal of carbon dioxide from the atmosphere through methods like the fertilization of the oceans, or pumping carbon dioxide into underground reservoirs. The other type is what I will call here "Targeted Planetary Cooling" (more commonly, but more limitedly, known as "Solar Radiation Management"), which is the idea that through processes such as injecting particles into the atmosphere or brightening the Earth's surface, we could reflect back more sunlight and thus reduce global warming.What is critical to point out here is that we are just at the very beginning of understanding the expected impacts and the risks of these kinds of measures. These measures are all at the stage of early exploratory research, with much to be done before any could be responsibly implemented. Much of the difficulty in assessing these proposals of climate engineering is due to the complexity of the Earth System. An example of this complexity was shown earlier in Figure 4: if we make targeted changes in one component of the Earth system, it will likely have impacts on many other components of the system.

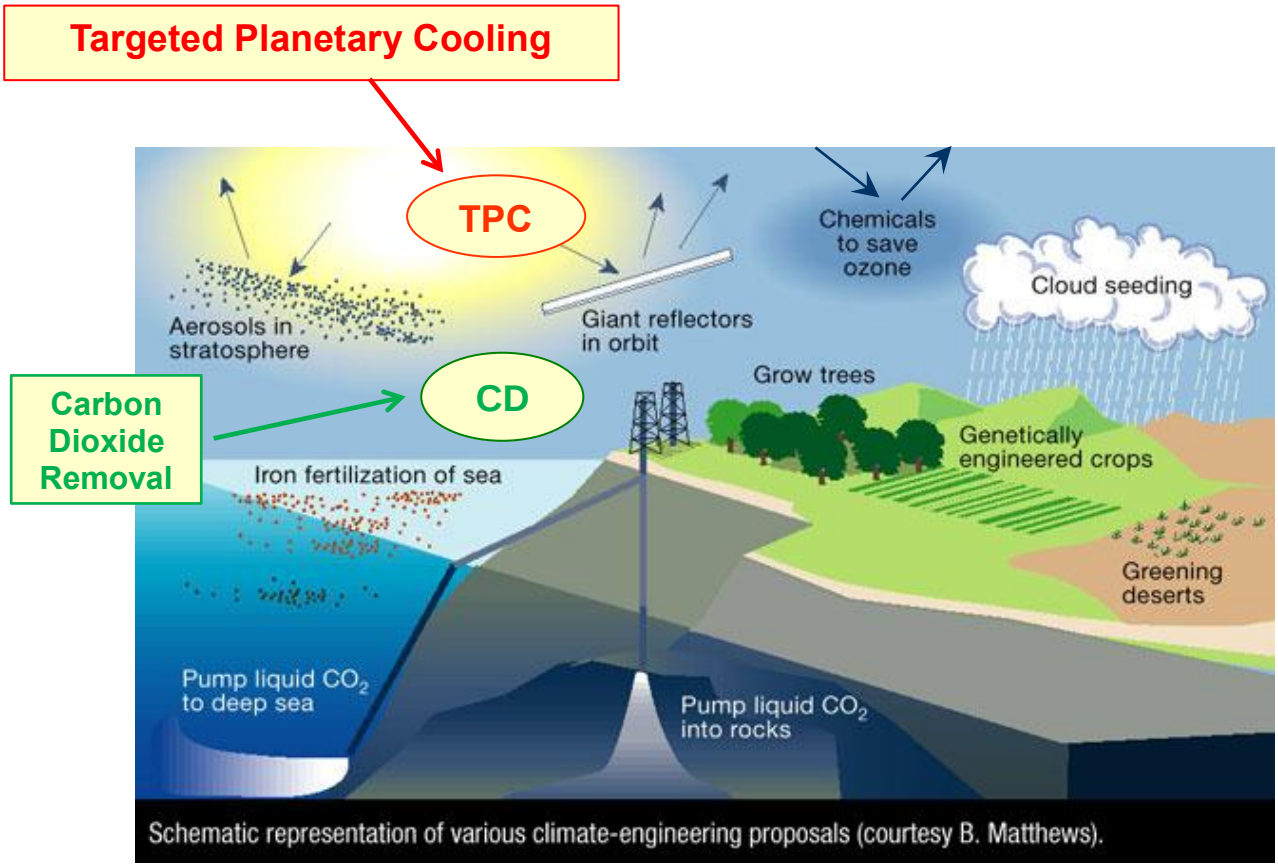

Figure 7: Examples of various proposed climate engineering techniques (from Kieth, *Nature*, 2001).

It is also important to realize that the risks involved are not only physical – there are also social risks for how the pursuit of these measures might influence national and international security, intergenerational equity, and even how they might affect the further development of our environmental consciousness, our understanding of our role in nature. I don't have the answers to all these difficult issues, nor does anyone else yet, but we are working hard on developing the holistic knowledge that will be needed to advise the public and policy makers effectively on this topic in the near future.

As I noted above with regards to the idea of "terraforming" Mars, and as is reflected in the discussions around climate engineering, there seems to be no end to our human ambition and fantasy when it comes to controlling and shaping our environment. But I'd like to ask you: can that same energy and creativity be redirected into marrying the evolution of technology with the evolution of our environmental consciousness, and using this to make steps towards a global society that lives in harmony with nature?

As a scientist, it is not my role to tell you which pathways or final goals you *should* choose. That doesn't excuse me from the responsibility to be very aware of the social and ethical implications of our work, and to answer to this responsibility by making our work transparent, communicating it well to the public and policy makers, and to the extent possible explicitly placing the value of making an important social contribution through broad-based collaboration above the competition for first results and funding. But it does mean that our role as scientists is to advise you, rather than decide for you; we can only offer you guidance by informing you carefully about the connections between actions and consequences – to the extent that we understand them – and by entering into difficult dialogues across various disciplines to help develop a more holistic understanding of the anticipated benefits and risks of various policy options.

To come to a close, I'd like to remind you that the technologically-oriented view of a world and a future in which there is an ever-growing influence of humans in the Anthropocene (as seen in Figures 1 and 7) is not the only way that the world can be or is being seen; this is reflected in the movement to develop an international program on Harmony with Nature, including as a first step a greater understanding of and respect for the traditional concept of "Mother Earth" (Figure 8), which was responsible for convening the Dialogue of the UN General Assembly at which the talk was given on which this manuscript is based.

Figure 8: Depiction of Mother Earth (With thanks to http://www.goddessgift.net/).

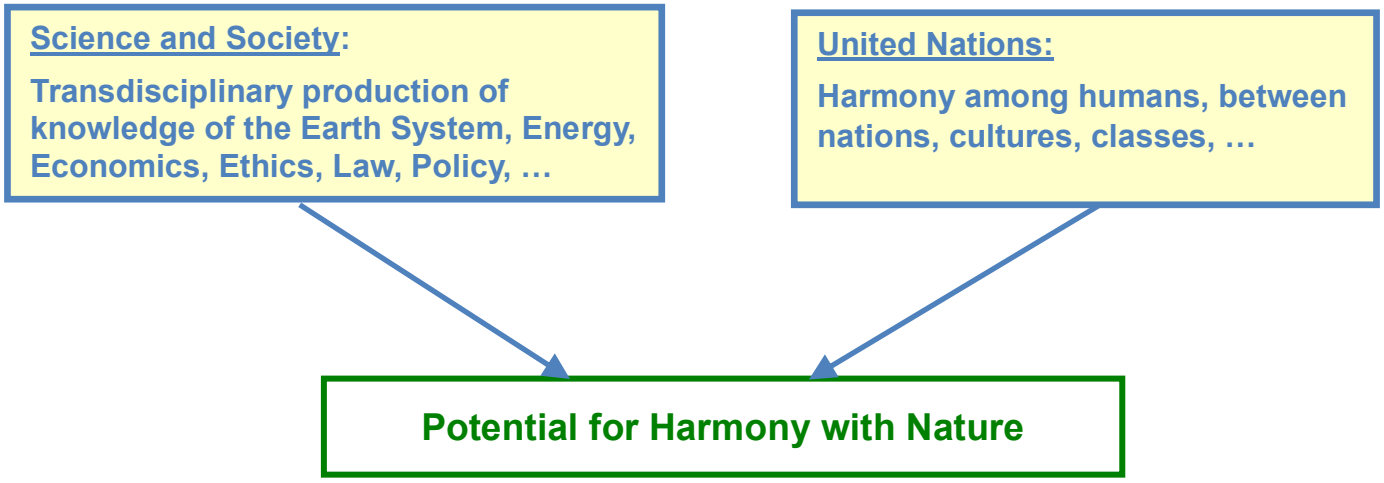

Figure 9: Elements on the way to Harmony with Nature.

I'd like to leave you with a couple of take-home messages. First, as I pointed out earlier, the Earth system is very complex, even without our human intervention. Adding to that basic complexity are the uncountable unintentional and intentional impacts of humans – who can perhaps be considered the "conscious part of the planet" – and that these impacts are so various and so planetary that no single indicator is sufficient to characterize all of the changes that we are experiencing. These vast changes are beingbroadly interpreted as clear evidence that we are now in the Anthropocene. The realization of this is going to be an important part of framing what we mean by "Harmony with Nature". To close, I would like to put forward two issues for further consideration. The first of these is what I call the "Cascade of Harmony". This Dialogue is about Harmony with Nature, which is at the far end of this cascade. That leaves the question: how likely is it that we can achieve harmony with nature, when we don't even live in harmony amongst humanity: between societies, within societies, with our neighbors and colleagues, and coming closer to home, even often with our families and friends? And most of us would certainly say, with our modern, frenetic lifestyles, that we don't really live in harmony with ourselves. Perhaps the goal of Harmony with Nature, through this cascade, will ultimately require – or at least would be powerfully supported by – developing and spreading ways for achieving and maintaining greater harmony with ourselves amidst the ongoing intensification of the interconnectedness and "always-on" expectations of modern life. This will of course not be easy – not at all. And science will not provide all the answers by itself. It will be important to develop effective transdisciplinary efforts, that is, close interaction between researchers and stakeholders (see the box on the left in Figure 9), in order to produce the knowledge that we

need for future sustainable development. However, as I suggested with the cascade of harmony, all the knowledge in the world might not help us much if we cannot apply it effectively from the basis of a harmonious relationship amongst humans – which is where bodies like the UN of course play a major role. Turning that around, even if we were to live in great harmony with each other, we would still have a desperate need for extensive knowledge of how to develop the technologies and lifestyle patterns that could support over seven billion people on this planet. So I'll end with an optimistic note, and say that if we can pursue these two activities effectively, and use them to guide the co-evolution of technology and our environmental consciousness, then we will have a great potential for eventually living in Harmony with Nature.